Space Weather Technical Forecast

Issued on Wednesday, 28 December 2022 at 13:24 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Risk of Minor Geomagnetic Storms throughout, peak Chance 30 December. Chance of M-class flares throughout. Chance or Slight Chance of Active electron fluence throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate over the past 24 hours with an isolated M-class (M1.2) flare from AR3169 at 27/1626UTC. There are five numbered sunspot groups on the disc and one unnumbered region that is emerging from the southeastern limb. The largest and most active region on the disc remains AR3176 (Eso/Beta) in the northeast, which has seen some further spreading and growth of intermediate spots. The second largest region on the disc, AR3169 (Fai/Beta), in the northwest has seen further fading of its minor intermediate spots. Other numbered regions are smaller and magnetically simpler, with slow decaying or stable trends.

Regarding potential sources of Coronal Mass Ejections (CMEs) in the period, most observed minor dimming activity was based on either limb, with a late prominence eruption (27/2100UTC) from the southeast near the assumed location of an arriving spot group, and a later one in the west at 27/2200UTC. One further CME has been observed on LASCO imagery around 28/0924UTC, however this is yet to be analysed by Enlil.

Solar Wind / Geomagnetic Activity: Solar wind speeds, as measured by DSCOVR and ACE at L1 have been Elevated in the low-500s of km/s in the past 24 hours on a relatively flat trend. The solar wind density was especially erratic, owing to differences in character between measuring satellites, however appears to have remained largely on a stable tendency at 9-12ppcc throughout. The IMF has been on a slowly declining trend and has remained weak. The north-south component, Bz, fluctuated between +6/-5nT throughout. Geomagnetic indices peaked, with a 62.0nT deflection in Hartland BGS Magnetometer at 27/1618UTC. The phi angle was mostly positive (away from the Sun) with short-lived negative periods (towards the Sun).
Geomagnetic activity was initially Active (Kp4) with a Minor Geomagnetic Storm G1/Kp 5 interval recorded 27/15-18UTC. Activity since then has tapered down to Quiet (Kp 0-2).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

High energy electron flux as recorded at GOES16 (greater than 2MeV), showed a rising trend as geomagnetic activity lessened into the UTC evening, with Normal Background flux eventually rising to a peak of High and 1630pfu at 27/1715UTC before waning. 24-hour integrated electron fluence followed a declining then recovering trend, recording 3.47e7 integrated pfu at 28/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity carries a daily Chance of M-class activity, with the main contributions from AR3169, AR3176 and perhaps the unnumbered group emerging across the

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southeastern limb. AR3169 is expected to depart the Earth-facing side through the course of Day 3 (30 December), with the chances of R1 correspondingly falling slightly but perhaps counteracted by uncertain contributions from any arrivals across the eastern limb.

Solar Wind / Geomagnetic Activity: Solar winds are expected to remain at or just above the Elevated threshold, before the arrival of a fast wind enhancement from CH59/+ due before the UTC weekend. A CME that left the Sun on 25 December may give a glancing blow to Earth on Day 2 (29 December), although this is low confidence. A CME is apparent on LASCO imagery around 28/0924UTC, but is yet to be modelled by Enlil.

There is a Slight Chance of G1/Minor Geomagnetic Storm intervals on all days, rising to a peak Chance on Days 2 & 3 (30-31 December) as a result of the relatively more reliable onset of the fast wind from CH59/+ (versus glancing CME arrivals).

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout, with a daily Slight Chance of reaching S1 levels.

High energy electron flux (greater than 2MeV) forecast is low confidence given the lack of utility of persistence methods (due to uncertainty in the arrival and effects of CMEs and significant coronal hole changes between rotations). Flux levels should persist close to or just above the Active threshold through Days 1 & 2, perhaps reducing for a time should any CME effects materialise on 29 December. The arrival of a HSS from CH59/+ is also expected to suppress flux levels by Day 3, before recovering over the course of the UTC weekend to an uncertain degree given the lack of a suitable analogous coronal hole from last pass. There is a Chance of Active fluence on Days 1 & 2, perhaps recovering late on Day 4 (31 December) into the New Year.

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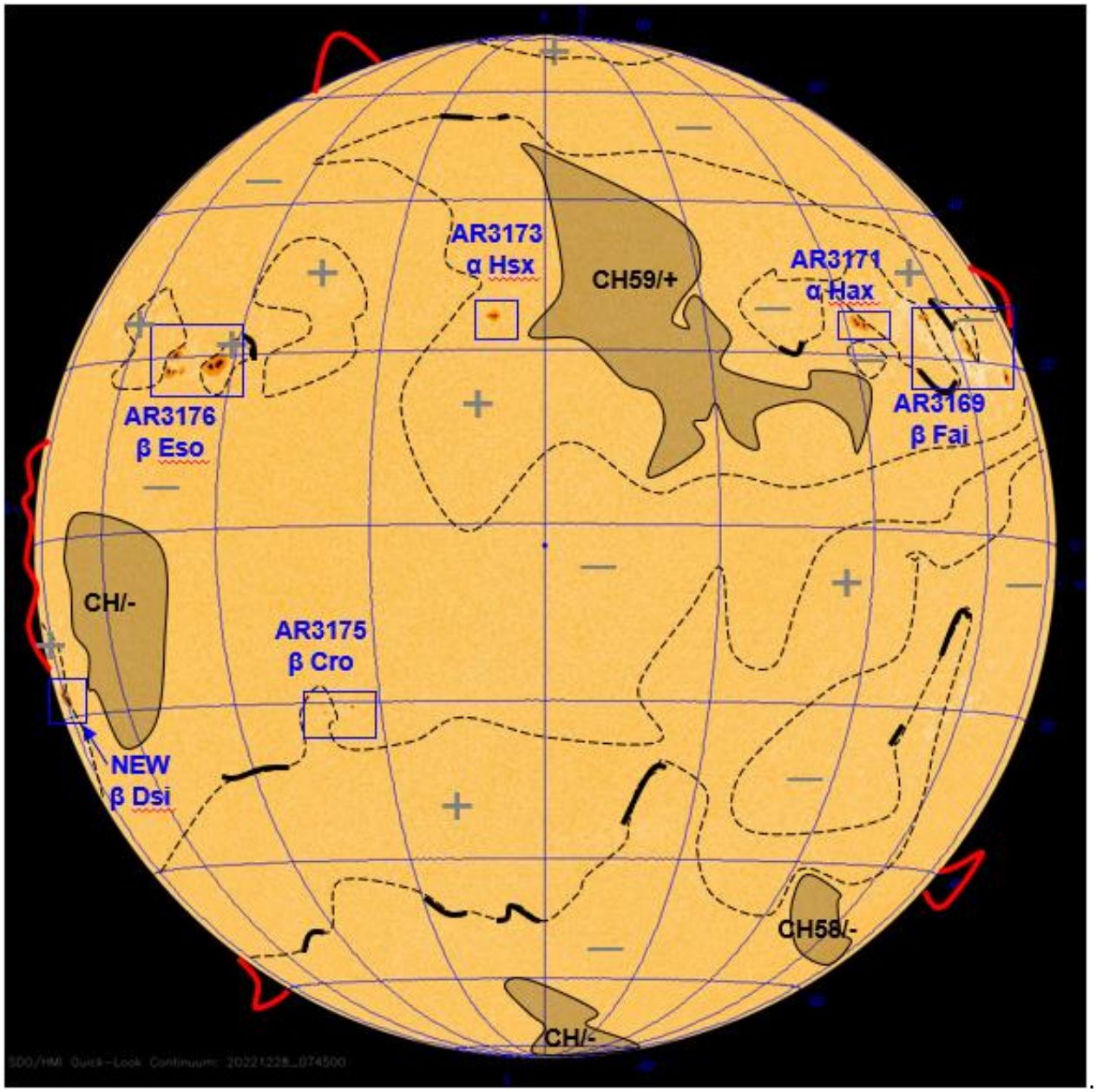
Figure 1. Solar Analysis Valid 28/0745UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

Solar wind speeds are currently around 510km/s, and are expected to remain close to or just above the Elevated threshold through Day 1 (28 December). A high speed stream from CH59/+ is expected to arrive through Day 2 (29 December), with enhanced Elevated, potentially Strong, solar winds persisting through much of the UTC weekend. CH59/+ is much changed from the previous rotation, as such, recurrence will not provide good guidance for geomagnetic activity nor solar wind strength.

A CME that left the Sun on 25 December, should pass 1AU on 29 December, giving a glancing

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blow to Earth, although this is a low confidence aspect of the forecast, with the CME assessed as mainly south and ahead of the Sun-Earth line. If this feature is late in arriving, then any impacts will be reduced or masked by the HSS.

A CME is apparent on LASCO imagery around 28/0924UTC, but is yet to be modelled by Enlil.
Geomagnetic activity is expected to be largely Quiet to Unsettled at first, with an increasing risk of Active periods and G1/Minor Geomagnetic Storm intervals through Days 2 & 3 (Thursday 29 & Friday 30 December), with this arising from the potential arrival of a CME from 25 December and the onset of CH59/+. The risk is expected to reduce through Day 4, as influence from CH59/+ wanes.

STEREO A is currently around a day upwind of Earth in sampling the solar wind at 1AU, and as such is not likely to provide any steer as to expected solar wind speeds until shortly before the event. This is compounded by significant gaps in data points.
MOSWOC Enlil suggests a gradual increase in solar wind strength through Days 3 & 4 (30 & 31 December), which is currently considered to be a little late given the shape and position of CH59/+ on the disc. Enlil wind speeds have consistently been lower than observed, but the overall trend for the forecast period can be seen to be reasonable guidance.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	10	30	40	20
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
25/1245	Partial	AR3169	NE Quadrant	520km/s	29 December	Low confidence

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Figure 2: MOSWOC Enlil showing arrival of CH59/+ HSS through Days 3-4. Weak signal for glancing blow on 29 December.

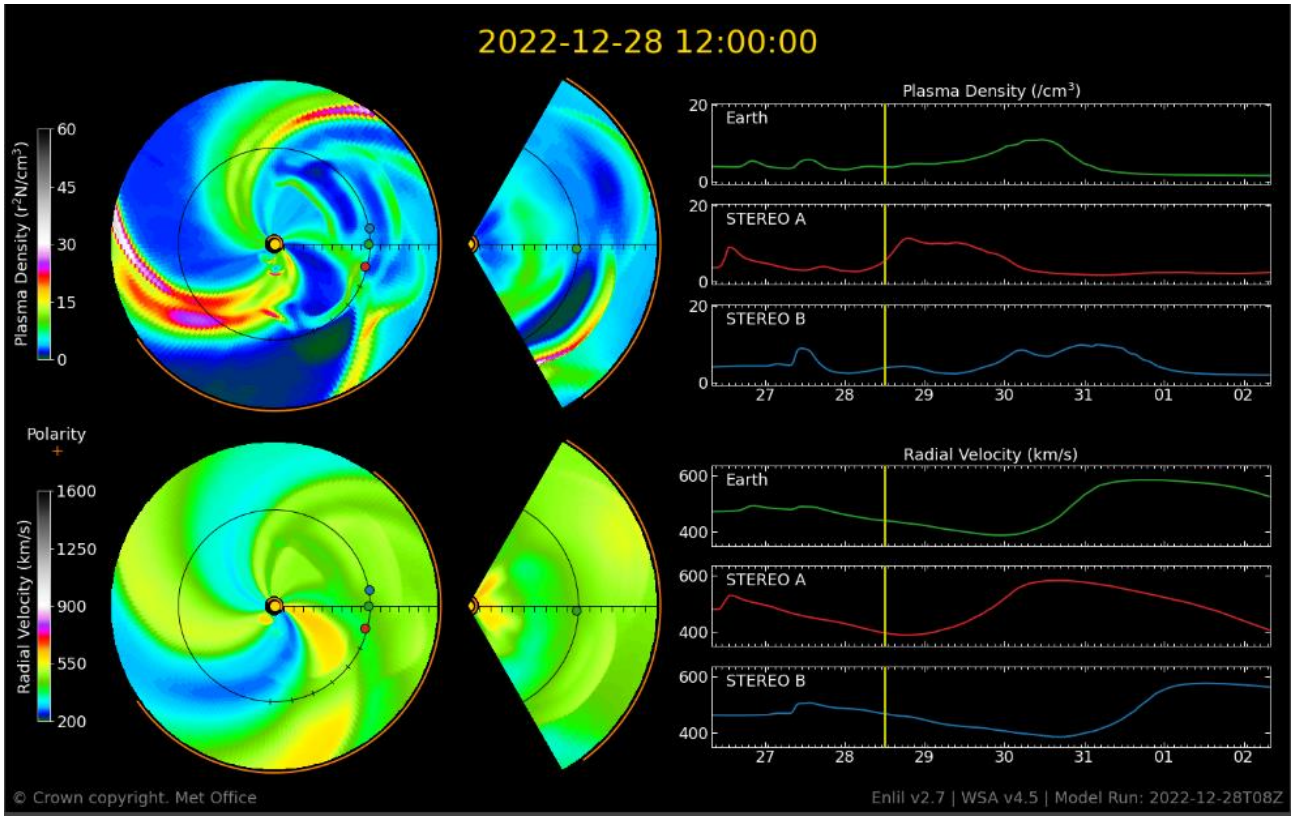
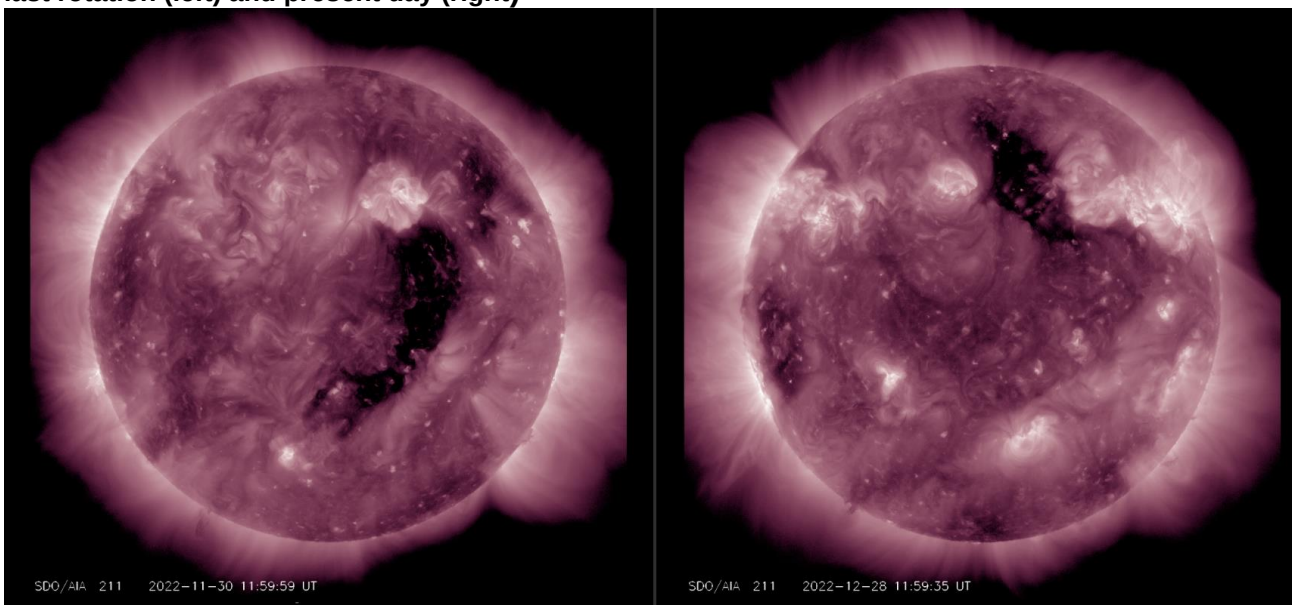


Figure 3: SDO/AIA-211 Imagery showing changes in coronal hole geometry and positioning between last rotation (left) and present day (right)



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Radio Blackouts - X-Ray Flares:

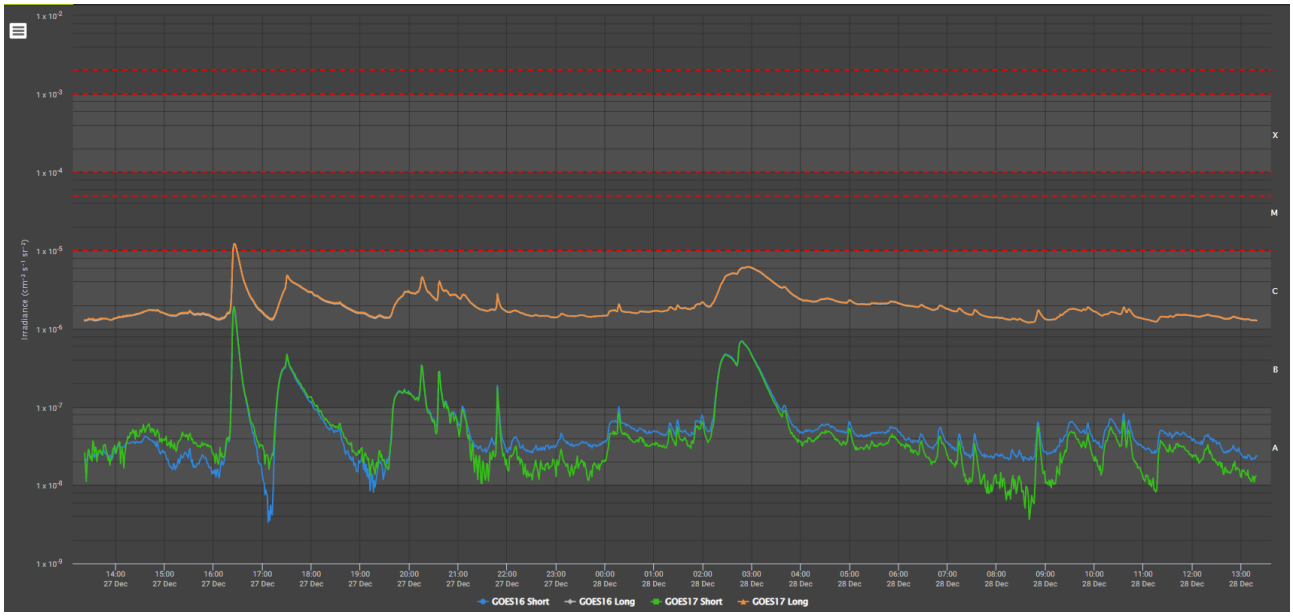
There are currently five numbered sunspot groups on the visible disc and one unnumbered region.

Solar activity is expected to be Low or Moderate, with a daily Chance of M-class activity through the period. Two large regions in the northern disc: AR3169 and AR3176 statistically pose the greatest risk of M-Class flares, along with possible contributions from the spot group emerging from across the southeastern limb. The main source of activity in both the last 24 hours and in the coming four-day forecast (barring development elsewhere) is most likely to be in AR3176, which has shown further spreading and growth of its intermediate spots. AR3169 is expected to depart the Earth-facing side through the course of Day 3 (30 December) with its contribution to daily risks ceasing by the UTC weekend.

Far-side soundings continue to suggest that there are sunspot regions lying close to the eastern limb that may emerge through the period. However, their presence is not yet confirmed and for now the X-ray flare risk is expected to fall with AR3169's departure.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	30
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 4:X-Ray Trace observed at GOES-16 & GOES-17



Solar Radiation Storms - (High Energy Protons):

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The high energy proton flux (greater than 10 MeV) is currently at Background levels, and is expected to remain generally unchanged through the period.
Forecast probabilities remain at a daily Slight Chance of S1 due to the ongoing possibility of larger flares from AR3169, AR3176 and possibly the unnumbered region as it continues to emerge from the southeastern limb. There have been no slight enhancements observed from any of the recent M-class flares of 27 December, and many of the spots in the eastern hemisphere are not likely to become geoeffective through the period, with any protons enhancements unlikely to be significant.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) at GOES16 has been suppressed at GEO during 27 December due to Geomagnetic activity, but has since recovered and remains at Moderate levels close to the High threshold. This recovery will perhaps be short-lived, with the possible glancing blow from the 25 December CME arriving on Day 2 (29 December) and the arrival of a HSS from CH59/+ by Day 3 (30 December). A recovery in flux values is possible towards the very end of the period, but will be dependent on the strength of the HSS and its impact on the radiation belts. The changes in the shape and position of the upcoming coronal hole compared to the last rotation results in persistence forecasting and REFM providing little in the way of a useful steer.

The corresponding fluence levels may exceed the Active threshold during Days 1 and 2 (28 & 29 December), but otherwise are expected to remain at Background levels. Recharging and recovery of the radiation belts towards their usual position expected towards the very end of the period on Day 4 (31 December) at which point the chance of reaching or crossing the Active threshold increases.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	40	40	20	30
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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